Lecture Notes in Peening Techniques and its Applications

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Surface Engineering Treatments (SETs)

Surface engineering treatments or SETs (the reader might also come along a different name that of Engineering Mechanical treatments). This science developed to enhance the mechanical chemical and physical properties of the materials. The applications widely used in aerospace, automotive, missiles, biosensors, textiles and metal working. The treatment can be used for wear resistance, fatigue resistance and corrosion resistance. The treatment can be done for ceramic, metals, polymers and composite materials [1].The surface treatment can be done by chemical or physical treatment. We focus onto the physical treatment, especially by using Laser Plasma Shock Peening (LPSP).

Peening Techniques

Peening is a process for working metals surface to improve its material properties such as hammers blows. The working by Peening for metals is cold metal working. The peening can improve the metal surface by increasing the compressed residual stress onto the surface.

The categories of Peening as below:

1. Shot Peening.

2. Ultrasonic Peening.

3. Water-Jet Peening.

4. Explosive Peening.

5. Roller Burnishing.

6. Laser Plasma Shock Peening.[2]

Shot Peening

In shot peening, the workpiece surface is impacted repeatedly with large number of cast steel, glass, or ceramic shot (small balls) as shown in Figure.1, this make overlapping indentations on the surface. This action causes plastic surface deformation at depth up to 1.25mm using shot sizes that range from 0.125 to 5 mm in diameter. The plastic deformation is not uniform throughout part's thickness. [2] Shot peening causes compressed residual stresses on the surface as shown in Figure.2, thus improving the fatigue life of the component by delaying fatigue crack initiation. Unless the process parameters are controlled properlythe plastic deformation of the surface can cause serve onto this surface, because of it the surface can be damage. The extent of deformation can cause gravity peening, which involving larger shot sizes but with fewer impacts on the workpiece surface.

Ultrasonic Peening

In this process, we use a hand tool based on a piezoelectric transducer. Operating at a frequency of 22 kHz, it can have a variety of heads for different applications as shown in Figure.3. [2, 3]

Water-Jet Peening

In this process, a water jet at pressure as high as 400 MPa impinges on the surface of the workpiece, inducing compressive residual stresses and surface and subsurface hardening at the same level as in shot peening as shown in Figure.4 [2,4]

Explosive Peening

In explosive peening, the surfaces are subjected to high transient pressure through the placement and detonation of a layer of an explosive sheet directly on the workpiece surface. The contact pressure that develops as a result can be as high as 35GPa and can

last about 2 to 3 μs. Major increases in surface hardness can be affected by using this method with very little change (less than 5 %) in the shape of the component. This technique used specially for Rail surface of the Railroad. [2]

Roller Burnishing

Roller Burnishing is a cold working process which produces a fine surface finish .The burnishing technology principle is based on applying a force to a roll or rollers which roll on the work pieces surface as shown in Figure.5. [5]

Laser Plasma Shock Peening

The basic principle for Laser Plasma Shock Processing (LPSP) as shown in Figure.6, A high Intensity Laser passes through optical lens. The optical lens focus the Laser beam onto the surface. The laser beam interacts with the black paint surface by etching very thin layer and vaporized the thin layer. The vapor

absorb from the laser energy and breakdown. This breakdown called plasma formation. The plasma formation spontaneously generates shock waves. These shock waves interact by equivalent pressure onto the surface with several Giga Pascal and change the surface deformation from elastic to plastic deformation. This is called Elasto-Plastic deformation. [2]

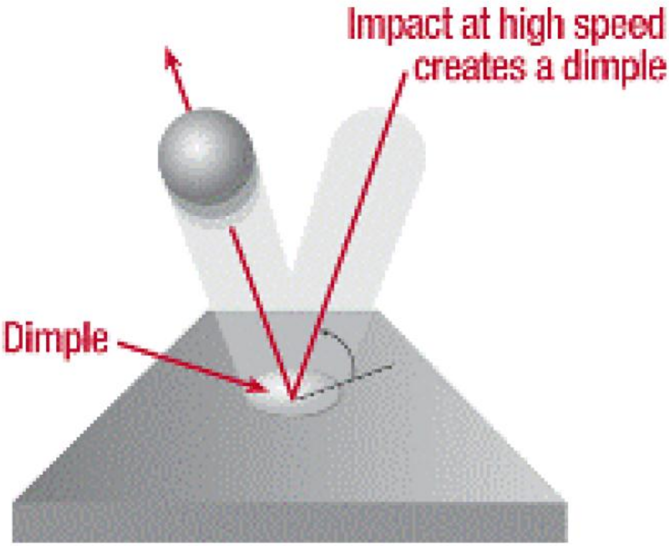

Fig.1 Impact at high speed creates a dimple

Fig.2 The Compressed Surface

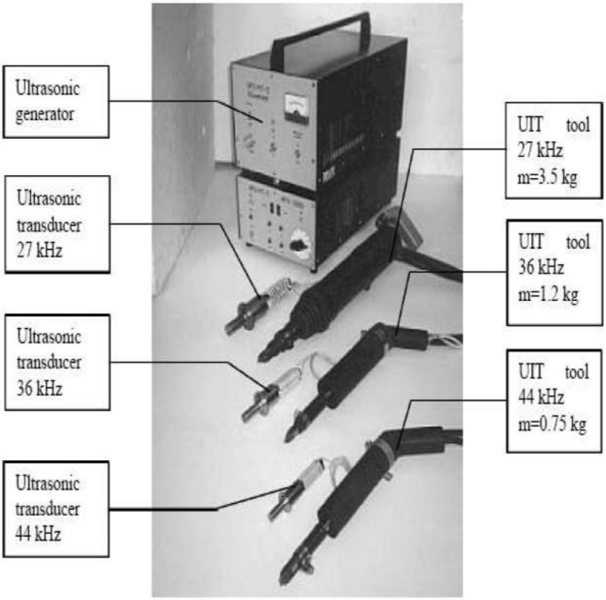

Fig.3 Computerized Complex for Ultrasonic Peening.

(UIT=Ultrasonic impact treatment)[3]

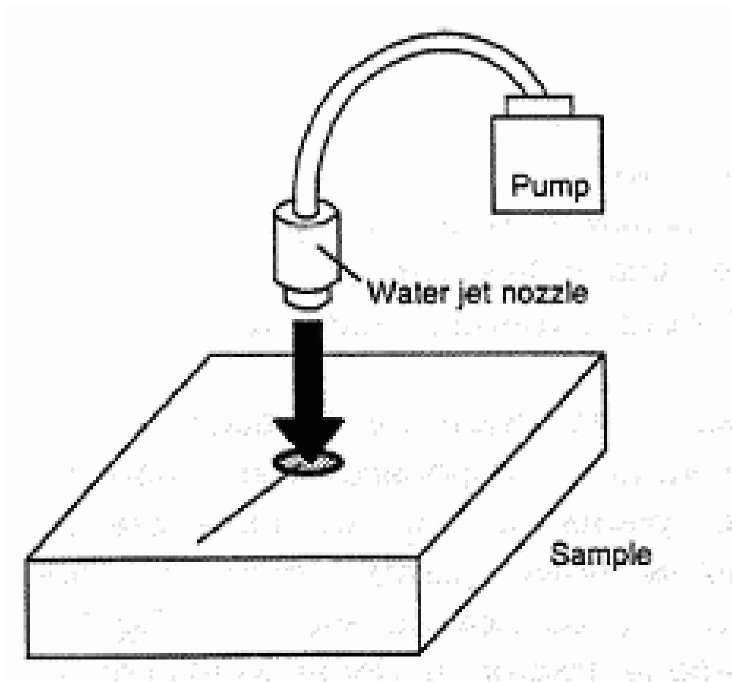

Fig.4 Simplified model of Water Jet Peening [4]

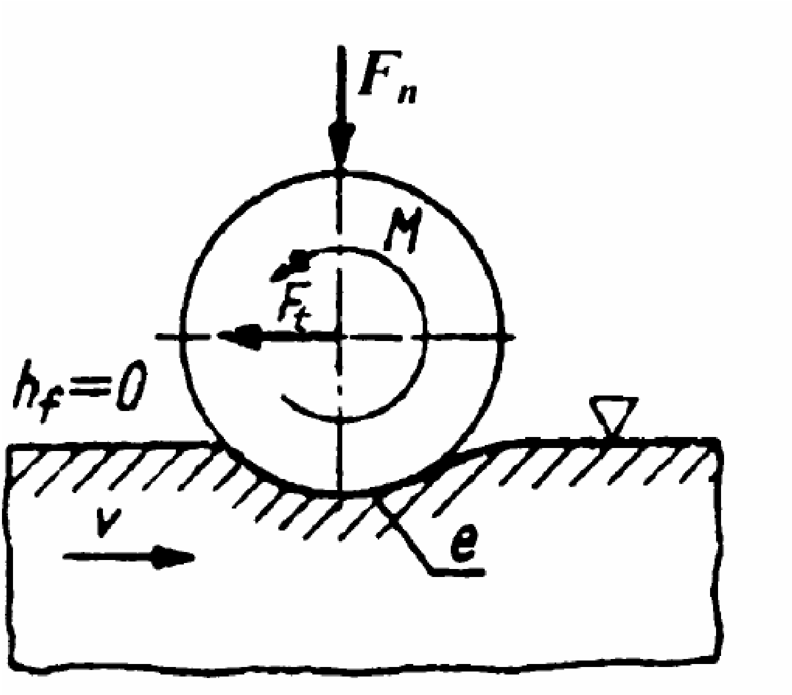

Fig.5 Simplified models of the rolling burnishing [5]

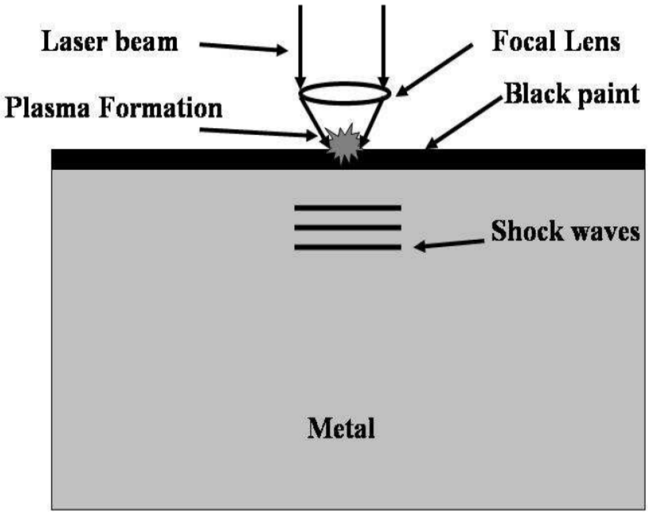

Fig. 6 Basic principle of Laser Plasma Shock Processing (LPSP)

The Degradation of Surface Engineering

Wear

Wear is a gradual process, much like the wear of tip of an ordinary pencil. The rate of tool wear depends on tool workpiece materials, tool geometry, process parameters, cutting fluids and characteristics of machine tool. Tool wear and the change in tool geometry during cutting manifest themselves are in different ways.

The wear can classify as shown in Figure.7:

1. Flank wear.

2. Crater wear.

3. Nose wear.

4. Notching.

5. Plastic deformation of the tool tip.

6. Gross fracture. [2]

Corrosion

Corrosion resistance is important aspect of material selection for applications such as chemical, food and petroleum industries. Resistance to corrosion depends on the composition of the material and on the particular environment.

Corrosive media may be chemicals as:

1. Acids.

2. Alkalis.

3. Salts.

The environment that can cause the corrosion can be as:

1. Oxygen.

2. Moisture.

3. Pollution.

4. Acid rain.

5. Fresh water.

6. Salt water.

Nonferrous metals, stainless steels and nonmetallic materials generally have high corrosion resistance. Steels and cast irons generally have poor resistance and must be treat their surfaces. [2]

Creep

Creep is the permanent elongation of a component under a static load maintained for a period of time. The mechanism of creep at an elevated temperature in metals generally is attributed to grain boundary. It is a phenomenon of metals and of certain non-metallic materials, such as thermoplastics and rubbers. It can occur at any temperature. Creep especially is important in high temperature application such as gas turbine blades and similar components in jet engines.

A typical creep curve usually consists of:

1. Primary.

2. Secondary.

3. Tertiary stages.

The specimen eventually fails by necking and fracture, called rupture or creep rupture as shown in Figure.8. [2]

Fatigue

In the manufacturing component and equipment such as tools, dies, gears, shafts and springs are subjected to rapidly fluctuating (cyclic or periodic) load in addition to static loads. Cyclic stresses may be caused by fluctuating mechanical loads such as on gear teeth or by thermal stress. Under these conditions, the parts fail at a stress level below that at which failure would occur under static loading. Failure is found to be associated with cracks that grow with every stress cycle and propagate through the material until a critical crack length is reached and the material fracture this known as Fatigue failure. This phenomenon is responsible for the majority of failures in mechanical components. [2]

Fatigue test methods involve testing specimens under various states of stress usually in a combination of tension and bending. The test is carried out at various stress amplitudes (S) and the number of cycles (N) it takes a cause total failure of the specimen or part is record.

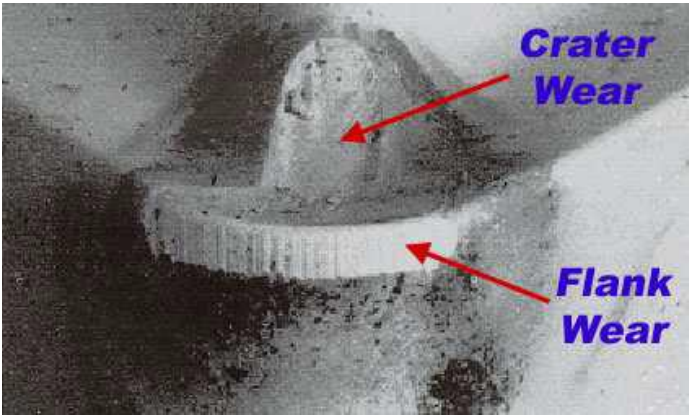

Fig.7 The difference between Crater wear and Flank wear

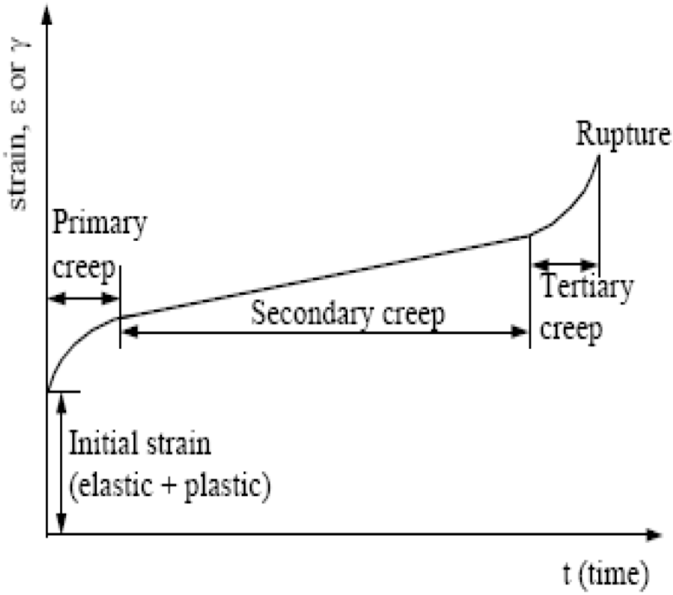

Fig.8 Schematic illustration of typical creep curve, the linear segment of the curve (secondary) is used in designing components for a specific creep life [2]

Laser Plasma Shock Processing (LPSP) applications

LPSP for Peening

The peening technique one of the most powerful technique for surface treatment, the material that treated by the peening can increase its resistance to fatigue creep and corrosion [6]. The peening has been succeed for Fan blades, cracks inside nuclear power plants surface and Jet Engine like F119, F35 and F22 as shown in Figure.9.[7]

LPSP for Semiconductor Dry Cleaning

Also the New development of Laser shock Peening that used for laser shock cleaning. This is a new dry cleaning methodology for the effective removal of submicron sized particles from solid surfaces as shown in Figure.10, 11. [8]

LPSP for Cladding

The cladding by laser-induced shock in vacuum glass confinements as shown in Figure.12, This process has been applicable in water confinement after evacuation of gas from the material and protecting the part by a thin foil bag similarly to the isostatic pressing technique. [9]

Ultrasonic Laser Sonar

This technique is used for High precision, non-contact and nondestructive measurement of various layers in an integrated circuit. The measure done for the reflected acoustic signal(timing, strength and width of the echo) that can analyze and determine film thickness , number of lyres , inter layer roughness and adhesion , interlayer contamination and the reactions between layers, with high precision.[10]

LPSP for Cataract Remedy

One of the best successive treatments in medical applications for removes the cataract as shown in Figure.13. Because of the cataract an organic material so it can be destroyed easily by the shock waves that generates from the Laser Plasma interaction. The accuracy of the laser put this technique in the medical applications for cataract removal in the best way for removing cataract. [11]

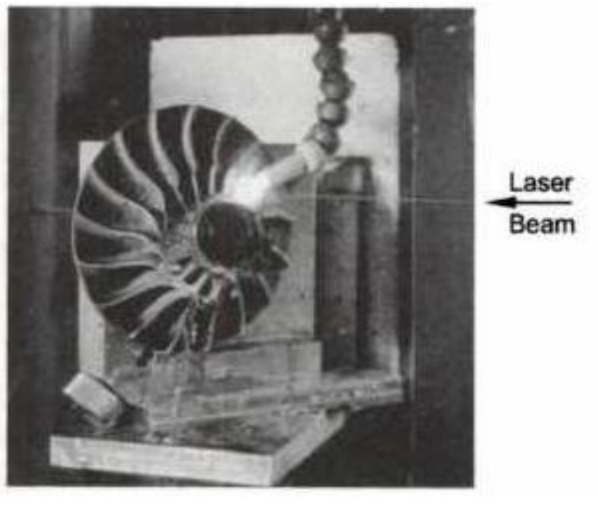

Fig.9 Aircraft engine peened by LPSP

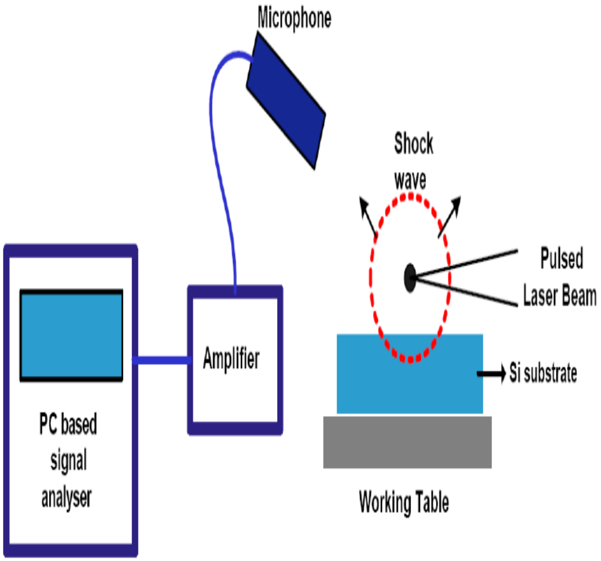

Fig.10 Schematic diagram of the experimental system for acoustic monitoring in the laser shock cleaning process [8]

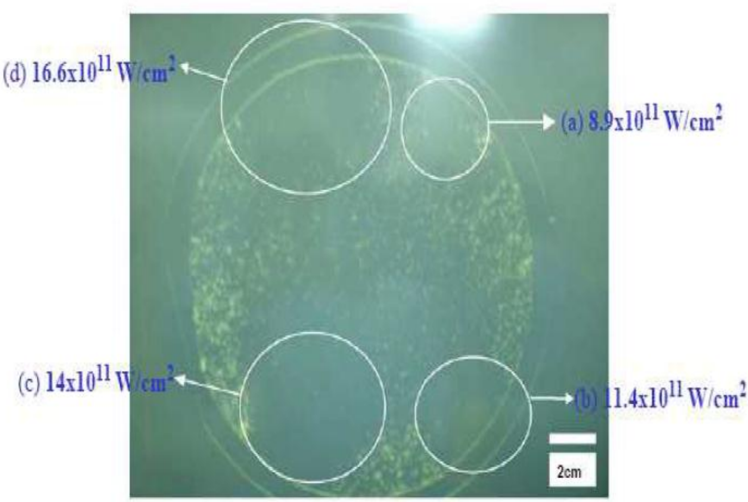

Fig.11 Scanned image of the wafer surface; (a), (b), (c) and (d) show the cleaned area after cleaning of the wafer surface by Laser shock [8]

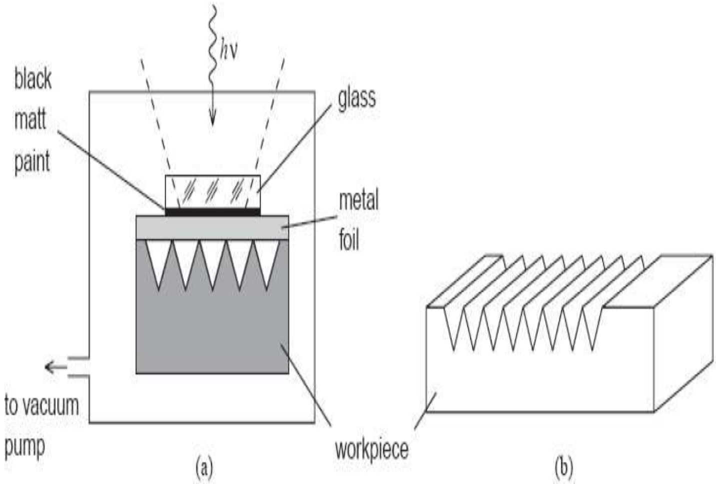

Fig.12 Cladding by laser shock, metal foil—Al [9]

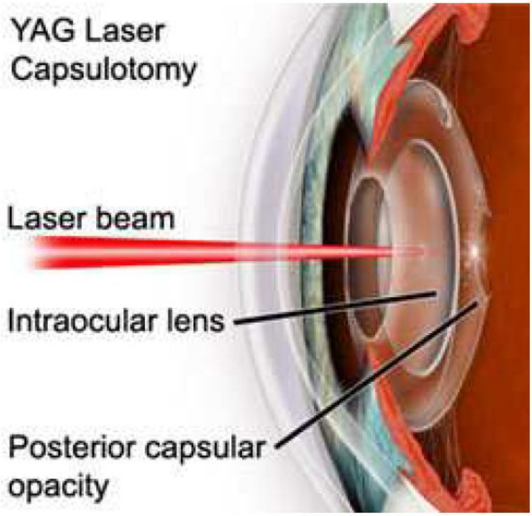

Fig.13 LPSP used in posterior Capsulotomy for cataracts

LPSP Models and Parameters

Laser Plasma Shock Parameters

Laser parameters

The main parameters for the Laser as shown below:

1. Laser Type.
2. Wavelength.
3. Pulse Energy (J).
4. Duration of laser Pulse (ns).
5. Repetition rate.
6. Pulse shape TEM.
7. Focusing (Spot Size).[2]

Plasma Parameters

1. The transparent material (water, glass, etc)
2. The Opaque material (black paint, aluminum foil, etc)
3. Laser Intensity>108 W/Cm2 For the Plasma Formation greater than or equal 1eV.[2, 12, 13]

Shock Waves Parameters

The main of the shock waves parameters are the materials shapes [spherical, plate, etc], because it can cause a reflection to the shock waves. [14]

Material Response for Peening

The response or un-response of the Material depends upon the Elastic-Plastic deformation (dynamic stress). Most of the researches had been considered the Laser Pressure range from 2 to 3 times than Hugoniot Elastic Limit (HEL).

Laser Shock with Unstable Waves

The Laser interaction with the matter can cause:

1-photon pressure for this pressure the photon not sufficiently to the material process because it nearly by kPa,

2-Thermal stress for this type of interactions without changing to the phase of the material and this typically as in the photon pressure,

3- gas recoil pressure for this type of interaction more sufficiently higher than the thermal stress, 4-Plasma recoil pressure this type of interaction with more high pressure and more sufficiently to produce change in the material deformation.

Laser Supported Combustion Waves

An interaction Lasers with chemical material this interaction can cause combustion waves, this reaction exothermal chemical reaction with a reaction rate that typically follows an Arrhenius law. [12, 15]

Laser Detonation Waves

This model more high pressure and sufficiently to describe the breakdown that cause from the interaction between the laser and the material to generate shock waves. [12]

Acoustic Impedance

The consideration for this model by using the interaction between the laser and the matter as in impedance of wave propagate inside the medium, which depend upon the sound velocity and the acoustic impedance. [22]

Laser Drive Deflagration Waves

The deference between the Deflagration waves and detonations waves as that; the detonation waves supersonic but the case in deflagration is subsonic. Because of dealing with the deflagration by using the multilayer perturbed surface because the pressure will appear after the ignition of the blast waves. [12]

Laser Shock with Stable Waves

The same situation as mention before but in this case we deal with stable shock waves. The stability of shock waves can be done by laser source with repetition rate greater than 5 Hz to let the shock waves stable [16] or using CW Laser system to produce affect as inthermal stress.

Laser Induced Thermal Stress

The thermal stress it is known as the change in temperature that can cause bodies to expand or contract. [17-19] This phenomena happen with considering the laser as thermal phenomena, but the shock waves that produced from this model not much higher because there is no changing in the interaction phase comparing to the shock that produce from the plasma phase .

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